Aleppo and Beyond: Options for Delivering Humanitarian Aid in Dangerous Conditions

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1 Executive Summary

Note: This paper took about 10 days to prepare. During that time, the situation in Aleppo has degraded even further, to the point of imminent collapse before the regime forces. By the time this paper is read, it may be too late to help Aleppo; nevertheless, it serves as a useful case study and guidance for future situations.

The siege of Aleppo has turned into a massive humanitarian crisis, with the lives of 275,000 civilian residents jeopardized by starvation and inadequate medical care during the increased bombing campaign by the Syrian regime. When all internal resources are depleted, the city would need at least 130 tons of aid delivered per day. While this is a large amount, it could be met using US military airdrop capabilities. Specifically, Joint Precision Air Drop Systems (JPADS), or a commercial equivalent, could be deployed from C-17s flying at or above 20,000 feet, and dropping from up to 25 km away. A sortie of 3 C-17s per day from Incirlik Air Base could meet the emergency needs of the civilian population. The US military has better and more equipment and training for this mission than the UN World Food Program or other NGOs. Any airdrop of aid should be closely coordinated with the Aleppo City Council. These airdrops could be continued until the available supply of precision airdrop systems is exhausted. This is the recommended delivery approach if the United States decided to take action in a highly visible projection of our nation's commitment and power to help alleviate immediate suffering of the Syrian people.

One of the leading concerns is cost. Rough estimates of cost for a high altitude airdrop is approximately $16,000 per ton of aid delivered (assuming commercial one-time use variant of JPADS); this is far more expensive than the estimated $2,500 per ton for ground transport, but its likelihood of mission success is far higher. It is therefore recommended that lower cost precision airdrop systems be developed, and a sufficient quantity stockpiled for future humanitarian crises like Aleppo. By leveraging commercial technology, a long-range, high altitude, precision airdrop system for bulk delivery could be developed with a cost target of $3,500 per ton. In today's world, it is very likely that situations like Aleppo will arise again, or even the need to deliver aid after chemical-biological-radiological-nuclear (CBRN) events, and it would be of great value for the US government to have better options available.

2 Introduction

The Eastern half of Aleppo is currently held by Syrian rebels[1] and is completely besieged by Syrian government and Russian forces. The world has been horrified by emerging reports of the deliberate attacks on civilians, including hospitals and schools. Furthermore, on Sep. 20, Syrian forces bombed a UN humanitarian convoy, destroying 18 trucks and killing 20 people. This has greatly complicated the objective of providing humanitarian relief to the civilian population of Aleppo. If the decision is made to help these people in urgent need, it is important to select the right approach to deliver that aid.

The purpose of this note is to recommend possible delivery approaches for providing relief to Aleppo, from a systems perspective. It is not intended to recommend policy or foreign relations, but simply provide options to support whatever policy is adopted going forward.

All numbers in this paper are rough approximations, and are only included to provide an order-of-magnitude estimate. They should not be relied upon for actual operational planning.

3 Problem Background

3.1 Situation in Aleppo

Aleppo is a city in Northeast Syria, and is currently divided by the Syrian Army in the west and moderate rebels in the East. Experts estimate there are about 275,000 civilian residents in the rebel-held area. East Aleppo is surrounded completely by a ring of regime forces; however, about 5-10 km to the west are additional moderate rebel-controlled territories; Kurds control areas to the northwest; and ISIS to the northeast. The nearest Syrian Defense Force (SDF) hubs are in Anadan (13 km NE) or Urem Al-Kubra (20 km SW). Humanitarian aid would likely be distributed from Idlib, which is about 55 km SW. If US military were to provide airlift, it may also originate from Incirlik Air Base, Turkey (about 180 km to the West). The Aleppo airport, though near rebel territory, is considered completely under regime control.[2]

The week ending Nov. 18 has seen the most intensive air attacks so far by the regime (including both Syrian and Russian aircraft). Hospitals and schools have been deliberately targeted. There are reports of chlorine barrel bombs also in use (see for example attack on Masakan Hanano neighborhood). Hundreds of civilians have been killed in the past few weeks alone. As a result of these attacks, the conditions in East Aleppo are dire. The World Food Program (WFP) expects that food aid is exhausted by Nov. 18, and though there is 100 tons of wheat stored by the local government, that too will be quickly depleted.[3] More urgently, all hospitals in the area have been damaged and most are inoperable. Water is contaminated in many areas, and there is an urgent need for medical supplies. There is also a need for fuel to run generators, at least for the temporary medical shelters.

One expert claims that genocide is imminent given the current escalation of attacks on civilians.[4]

There is an organized city government (the Aleppo City Council, ACC) within the besieged area, that still provides city services. There are some reports of civil unrest in response to the imminent food

[1] Current rebel groups known to be operating in Aleppo include: Fatih al-Sham, Ahrar al-Sham, Suqoor al-Sham, Jund al-Aqsa, Faylaq al-Sham, Liwa al-Haq, Jeish al-Sunnah, Ajnad al-Sham (source Hala Systems)

[2] Information provided by sources contacted by Hala Systems

[3] https://www.enca.com/world/our-depots-are-empty-food-aid-runs-out-in-syrias-aleppo, accessed 11/23/2016

[4] Information provided by sources contacted by Hala Systems

shortages, but it is believed that there is still a local government partner that could help disseminate aid if any were provided.[5]

The regime conducts airstrikes and artillery attacks that can access the entire rebel-controlled East Aleppo area. It is believed that regime forces have manpads, but there is not evidence at the unclassified level of more sophisticated air defense command and control or capabilities. [6] The Russians, on the other hand, certainly have air defense systems capable of shooting down aircraft at high altitudes. However, whether they are willing to openly shoot down UN or US aircraft on humanitarian missions is not certain; it would definitely escalate the conflict with the Russians as the aggressors.

3.2 Humanitarian Aid Background

The most critical needs are medical supplies, fuel, food, and water. In the current crisis, water can be purified with chemicals (iodine, chlorine) and filters. This is a negligible weight compared to transporting fresh water. Medical supplies are also far smaller and lighter than other bulk items.

This leaves fuel and food as the major weight drivers for transport. Diesel fuel weighs 850 grams per liter. A typical diesel generator at 100% load can provide about 100 kWh of electricity from 28 liters of fuel. 100 kW can roughly power an austere 50-bed field hospital. Assuming a population of 250K, that would normally require about 150 beds.[7] Therefore, just for emergency medical treatment, one would require 84 liters per hour, or 1,700 kg of diesel per day.

Humanitarian food relieve requires provision of 2100 kcal per person per day.[8] The US military in the past has deployed Humanitarian Daily Rations (HDR), which are individual packages designed for free-fall airdrop, and can feed one person per day; they cost $4.70 per package and weigh 850 g.[9] In bulk packaging, food is cheaper and lighter, typically the required food in bulk can be about 500 g per person per day.[10] To completely feed 250,000 people would require about 125,000 kg of food per day, which is by far the largest requirement.

For rough approximations, there needs to be about 130 metric tons of aid delivered per day to completely sustain the civilian population.

4 Aid Delivery Options

The question becomes, what is the best way to deliver 130 tons of aid per day? There are several criteria to consider, including: quantity of aid, cost of delivery, risk to recipients, risk to deliverers, ability to penetrate the siege, and distribution of aid.

4.1 Approach Descriptions

4.1.1 Ground

[5] Information provided by sources contacted by Hala Systems

[6] Information provided by sources contacted by Hala Systems

[7] https://www.redcross.fi/about-red-cross/our-work-throughout-world/general-field-hospital, accessed 11/23/2016

[8] UN World Health Organization, “Food and Nutrition Needs in Emergencies,” 2004.

[9] Programs Directorate HADR and Mine Action Division, “Humanitarian Daily Rations,” Information Paper, July 2012

[10] UN World Health Organization, “Food and Nutrition Needs in Emergencies,” 2004.

Trucks on the ground can move the most weight for the lowest cost, by far. The global average cost for WFP planners is about $180 per ton.[11] In conflict regions, that number will rise significantly; the current estimate for this conflict is about $2,500 per ton.[12] Nevertheless, that is still cheaper than any other alternative. Volume is also not a problem. A typical freight truck can carry about 20 tons—so 8 trucks per day could satisfy the Aleppo requirement.

With a ground-based convoy, it is assumed that aid packages can be delivered safely to residents, and that personnel accompany the aid to ensure fair distribution.

On the other hand, currently the regime will not allow ground vehicles in or out of Aleppo. Ground transport would be the most vulnerable to attack or at least hindrance. Even if the regime did not want to attack the convoy (due to fears of international repercussions or other escalation), ground transport can simply be stopped with roadblocks. Ground transport by the US military in this scenario would almost certainly risk open conflict.

If the leading concern was simply safety of the delivery personnel, teleoperated vehicles could be employed; however, that does not solve the leading challenge of gaining access to the besieged area.

4.1.2 Airlift

The next option is to consider delivery via air. The U.S. military Joint Publication 3-17 outlines the multiple options for airlift, including airdrop (parachutes) and airland (landing and unloading). Airland is typically the preferred method, but in this case is unavailable due to lack of a suitable landing zone.

Airdrop involves flying a cargo aircraft over a designated Drop Zone (DZ) and releasing the aid while still airborne. The cargo may free-fall, use high-velocity parachutes (landing at about 60 mph), or low velocity parachutes (landing <20 mph). Low-velocity parachutes are larger and more expensive. In the past, food packets like the HDRs or even large bundled sacks of bulk grains have been airdropped using freefall methods with no parachute at all. HDRs are released individually in the air and scatter broadly across the DZ. Typically, for humanitarian airdrop, the cargo is dropped from altitude below 500 feet; this minimizes the uncertain impact of wind on landing location.[13],[14] However, the military routinely drops from higher altitudes, even from 20,000 feet. High altitude drops may require guidance systems to be able to land cargo within the DZ, especially if it is a small area.

Airlift provides much better access than ground transport. Aircraft cannot be stopped by roadblocks; the only stop would be use of lethal force to shoot down the aircraft. It is unclear if the will to do that exists. It is not expected that Syrian forces have the current capability installed necessary to shoot down a C-130 or C-17 equipped with countermeasures at 20,000 feet, though the Russians likely do have the capability. There is certainly risk, but it is much lower than the risk for ground convoys, and does not carry as much risk of open conflict.

Humanitarians typically view airdrop as a method of last resort. Besides the cost, the other concerns they cite are: 1) the inability to assess the needs of those being assisted, 2) the risk of people being hurt by falling cargo, and 3) the inability to control distribution of the aid to the most vulnerable populations. Most of these concerns can be mitigated somewhat with proper coordination with the ACC. One source recommends using Jisr Al Hajj, a major road junction in Aleppo, as a DZ;[15] it is open and lies in a central location of the rebel-held territory. It is on the order of 200 m in diameter.

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[11] World Food Programme, “WFP Logistics in 2012: Changing the Way We Deliver,” 2012.

[12] Information provided by sources contacted by Hala Systems

[13] http://www.irinnews.org/feature/2009/07/30/how-do-food-airdrop, accessed 11/23/2016

[14] http://www.cnn.com/2016/06/03/middleeast/airdrops-humanitarian-aid-syria/, accessed 11/23/2016

[15] Information provided by sources contacted by Hala Systems

Regarding cost, there are several components to consider. There is some cost for wrapping and packaging the cargo in preparation for airdrop. These are small though compared to the aircraft and parachute costs.

The US uses several different aircraft for airdrops, ranging from the CASA-212 carrying 3 tons to the C-17 carrying 45 tons. There are several different data points for aircraft costs, here are a few:

- One commercial airdrop provider that operates in Iraq quotes a cost of $7,700 per flight hour for a cargo aircraft, as well as $300K per month for crew and aircraft.[16] If we assume 4 of the commercial aircraft make 2 3-hour flights each per day, the cost would be about $2,000 per ton just to fly the aircraft.
- The DoD quotes the C-130J cost of $6,900 per flight hour,[17] or a total ownership cost of $14,000 per flight hour.[18]
- The DoD also quotes the C-17 cost of $15,800 per flight hour.[19] Using the C-17, the cost would be about $1,000 per ton.

The largest cost driver of airdrop is the parachute system. The decision of what parachute to use is driven by the altitude of the airdrop, and the altitude is primarily driven by the danger of air defenses used against the delivery aircraft. If the aircraft can drop cargo from a low altitude, then food and many supplies can be dropped freefall, with no additional parachute cost. If the cargo is dropped from a high altitude, it must have some type of guidance system to be able to drop into the urban environment.

There are two advantages of using high altitude airdrop. The first is there are fewer SAM systems or small-arms that can engage an aircraft at high altitudes. The other advantage is that guided parachutes can glide up to 25 km from high altitudes. This allows the aircraft to remain over rebel controlled territories when releasing its cargo.

The Joint Precision Air Drop System (JPADS) used by the US military is the leading candidate parachute system for high altitude drops. It uses GPS and active control of a drogue chute to steer the package during decent; JPADS has demonstrated ability to land reliably within 200 m.[20] Because of its active control design, it can achieve this accuracy even from high altitudes. JPADS comes in at least two variants: the 2K system which carries 2,000 lbs, and the 10K system which carries 10,000 lbs. The 2K JPADS systems is approximately $20,000. Surprisingly, the 10K is not much cheaper per ton than the 2K system. In large quantities, using commercial GPS rather than military GPS, and using one-time-use parachutes, the cost could be reduced to about $15K per ton (estimate).

Airdrop is expensive. Even for low-altitude drops, the WFP claims costs of approximately $1,600 per ton[21] in one reference, or on a global average of $3,500 per ton in another;[22] these estimates are in line with the cost estimates above. For precision airdrop, adding the parachute to the aircraft cost, the delivery cost rises dramatically to at least $16,000 per ton.

4.1.3 Unmanned air vehicles

[16] Source is company proprietary, but available upon request

[17] Office of the Under Secretary of Defense (Comptroller), "FY2016 DoD Fixed Wing and Helicopter Reimbursement Rates," 2016, http://comptroller.defense.gov/Financial-Management/Reports/rates2016/

[18] http://nation.time.com/2013/04/02/costly-flight-hours/#ixzz2Po5pdKbQ, accessed 11/23/2016

[19] Ibid. 17

[20] Benney, et al, "DOD JPADS Programs Overview and NATO Activities," 19th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, 21 May 2007, Williamsburg VA, AIAA 2007-2576

[21] https://www.devex.com/news/aid-drops-what-you-need-to-know-84216, accessed 11/23/2016

[22] World Food Programme, "WFP Logistics in 2012: Changing the Way We Deliver," 2012.

Some have floated the idea of using unmanned air vehicles (UAVs, sometimes referred to as "drones") to deliver aid into Aleppo. There are a wide range of UAVs. Most are outfitted as sensor platforms without any capacity to carry cargo. However, there are some that feature delivery of aid. On one hand, there are systems like the commercial "Zipline"; this is a small fixed-wing system that is being used to deliver medicines in sub-Saharan Africa, and has a 10 pound payload.[23] On the other end of the spectrum, there is KMAX, an autonomous rotor-craft sold by Lockheed Martin. It can carry 6,000 pounds, and was used by the Marines in Afghanistan from 2011-2014.[24]

The Zipline UAV system clearly has insufficient payload to carry 130 tons per day. Even the KMAX would require more than 40 flights per day, which would exceed current production capacity. Furthermore, the low-flying, lower speed rotorcraft would be far more vulnerable to regime air defenses.

UAVs will be expensive, do not have the capacity scale, and are technically less mature. The only problem they help with is relieving the danger to flight crews, but in no other way improve probability of mission success.

UAVs are not recommended as a delivery option for Aleppo. However, additional development of cargo-scale UAVs is encouraged for future scenarios.

4.1.4 Unconventional

Unconventional delivery modes were also considered. These included gliders, actual zip lines, blimps, balloons, and catapults. None of these had the scale or technical maturity for an immediate application. Furthermore, all of the ideas had significant performance, cost, or safety concerns, or had no additional advantage over traditional delivery methods. Therefore, they were not pursued further as near term options.

4.2 Evaluation Summary

The table below summarizes the assessment of the alternatives.

Mode	Cost per Ton*	Capacity	Recipient Safety	Crew Safety	Distribution	Access	Tech Maturity
Ground	$2,500						
Airdrop (low altitude)	$2,500						
Airdrop (high altitude)	$16,000						
UAV Options	--						

Rough approximations; actual value determined by conditions and specific systems used

Based on the assessment, high altitude airdrop is the best alternative for mission success. However, it is by far more expensive. There is also the pragmatic concern that current JPADS inventories would be depleted after just a few days. This presents a dilemma for planners and policy makers.

Even though it is more expensive, the high altitude airdrop is recommended due to the decreased risk to the air crew and increased likelihood of mission success. The recipient safety and distribution

[23] https://techcrunch.com/2016/10/13/a-test-flight-with-zipline-makers-of-humanitarian-delivery-drones/, accessed 11/23/2016

[24] Lockheed Martin, "K-MAX: A Revolutionary Unmanned Aerial System, Heavy Lift Cargo Operations," Presentation 2016, see also: http://www.lockheedmartin.com/us/products/kmax.html

parameters can also be improved through robust coordination with local government in the arrangement of the actual airdrops as well as management of aid distribution on the ground.

4.3 Future Options

Airdrop is a very attractive option in its freedom of access, but it is very expensive. In theory delivery of bulk goods for humanitarian purposes could be much less expensive. Single-use parachutes can be used. Commercial GPS would also be used, and a lower cost guidance system can be built. The system would not necessarily be built or tested to full MILSPEC standards. Bulk humanitarian goods can tolerate high velocity impacts. And when the alternative is starvation, lower performance and reliability is acceptable. Under these lowered requirements, it is believed that a precision airdrop system can be deployed for under $3,500 per ton (in large volumes). Even with a very conservative 80% success rate, this would be far more cost effective than a more expensive, high reliability system like JPADS. MIT Lincoln Laboratory would require a 6 month program to design, build, and test a prototype capability, and then transfer to an industry partner for manufacture. This development program would cost approximately $3M, including prototype flight testing.

Natick Soldier Research Development and Engineering Center (NSRDEC) is also pursuing a distributed humanitarian aid system, the Humanitarian Operations Packaged Essentials (HOPE) system. This provides yet another alternative to airdropping supplies, and could be fully developed within a few months for a near-term capability.[25]

For longer term research, there seems to be a capability gap for large unmanned cargo aircraft. A scenario like this would benefit from an unmanned C-130 variant, for example. From a technology point of view, this would not be much more difficult than current UAVs, but would deliver cargo rather than carry sensors or weapons. As opposed to the K-MAX, this would carry 18 tons or more, and be fixed-wing for longer ranges and higher altitudes. More non-traditional drop systems can also be considers for longer-term development; one example would be disposable gliding systems that are released at high altitude and long standoff ranges.

A precision humanitarian airdrop system could also be useful in a wide range of other relief scenarios. Specifically, this would be an important capability to have to support an at-risk or quarantined population after a chemical, biological, radiological, nuclear (CBRN) attack or disaster. The lower per-unit cost would make stockpiling the systems in advance of any emergency or crisis more affordable.

5 Airlift Precedents

5.1 Recent US Military Humanitarian Airdrops

The US military has undertaken many humanitarian airland operations (also referred to as air bridges). They have also conducted several airdrops in the past fifteen years. Some of these include:

- In August 5-13, 2014, C-17s and C-130s airdropped food and water to Yazidis displaced from their homes and awaiting rescue on Mt. Sinjar in Iraq. The US military delivered over 120 tons of goods over the course of about 5 days.[26]

[25] http://nsrdec.natick.army.mil/media/fact/, accessed 11/23/2016. Thanks also to Richard Benney of NSRDEC for sharing his expertise.

[26] http://www.wsj.com/articles/u-s-military-airdrops-fourth-delivery-of-food-water-to-yazidis-1407724680, accessed 11/23/2016

- In October, 2001, US military operations were just beginning in Afghanistan, which disrupted ongoing food relief efforts to alleviate four years of drought in Helmand Province. From Oct 7 – Oct 24, 785,000 HDR packets were airdropped (this is approximately 670 tons of aid).[27]
- In 2010, as part of Operation Unified Response following the Haiti Earthquake, the US military airdropped goods, on Jan 18 it dropped about 25 tons of aid in immediate response. Over the next three months, it would also airland over 2,000 tons of aid from overseas.[28]

The US military at the height of the Afghanistan conflict would airdrop over 100 tons per day (3 fully loaded C-17s) on a daily basis. While that was for military resupply purposes, it does demonstrate that the capability and scale exists, if the will and funding is there.

5.2 The Berlin Airlift

The most dramatic humanitarian airlift operation was the Berlin Airlift, and was led by the US military. From June 26 1948 to May 1949 the United States and Britain supplied food and fuel to West Berlin after the Soviets had cut off all land access. The population was about 2 million people, and planners estimated there was a need for 1,500 tons of food and 3,500 tons of fuel per day. The first day of operations delivered 80 tons of cargo; by August 1, they were up to 4,500 tons per day. One plane was landing every 45 seconds to reach this capacity. In all, the airlift would bring in 2,325,000 tons of cargo, completely meeting the needs of the civilian population. Though this operation involved airlanding rather than airdrops, since the airplanes landed to be unloaded, it is nevertheless impressive for the sheer volume of cargo and number of aircraft involved.[29]

This feat demonstrated to the world the commitment and the capability of the United States to stand against oppressive regimes and support its fledgling allies. It is especially remarkable that this aid was being delivered to German civilians, the same people who three years earlier had been fighting against U.S. soldiers. The experience also demonstrated the ability of the military to evolve and improve its operational capacity when called upon to do so. This dramatic use of air power for humanitarian aid helped shape a moral and political power that has influenced US - European relations for the better ever since.

6 Recommendation

Based on this quick-look assessment, it is recommended that if the United States decides to provide humanitarian aid to Aleppo, and if ground convoy passage cannot be negotiated, that the United States consider using high-altitude airdrop to accomplish the mission. It is further recommended that the US military carry out the airdrop, having the most expertise in doing so. At this point, it should be assumed that precision air drop systems (such as JPADS or a commercial variant) should be used to accurately land the cargo within the desired DZ from high altitude. This increases the delivery cost, but minimizes risk to the aircraft and crews in an active conflict zone. Cargo would be staged and prepared at Incirlik Air Base, and dropped at Jisr Al Hajj within rebel-held Aleppo. The airdrop operations must be closely coordinated with the Aleppo City Council (ACC) for protecting civilians near the DZ and ensuring fair distribution of the goods.

Rough approximations suggest that the cost of high altitude humanitarian airdrop may be on the order of $16,000 per ton. By typical humanitarian standards, this is very expensive. But, it provides the

[27] http://www.globalsecurity.org/military/library/news/2001/10/mil-011024-usia09c.htm, accessed 11/23/2016

[28] http://www.cnn.com/2010/WORLD/americas/01/18/haiti.airdrop/, accessed 11/23/2016

[29] https://history.state.gov/milestones/1945-1952/berlin-airlift, accessed 11/23/2016

highest likelihood of mission success, which is saving the lives of 250,000 people who will likely starve without intervention. At this cost point, completely supplying the people of Aleppo would cost approximately $2M per day. Though this is expensive, it is in line with other air operations conducted by the United States in Syria; one estimate shows the US spending about $12.6M per day for current bombing missions.[30]

It is also recommended that further development work be done to reduce the cost of precision airdrop systems. MIT Lincoln Laboratory estimates that a near-term humanitarian precision airdrop system could be developed which would cost $3,500 per ton. For even longer term research, larger unmanned cargo vehicles should also be developed and added to the inventory for both complex humanitarian operations as well as combat resupply missions.

This paper does not propose new policy. However, if the United States does decide to intervene in saving the lives of 250,000 Syrian civilians, the capability to do so exists within the U.S. military. Situations will continue to arise when the capability of delivering aid to difficult-to-access areas will be necessary. Research, development, and acquisition should be done now to provide cost-effective solutions for future crises.

[30] http://www.defense.gov/News/Special-Reports/0814_Inherent-Resolve, accessed 11/29/2016